

GUIDELINES FOR THE DESIGN AND CONSTRUCTION OF ROADS USING COIR GEOTEXTILES



**INDIAN ROADS CONGRESS
2022**

GUIDELINES FOR THE DESIGN AND CONSTRUCTION OF ROADS USING COIR GEOTEXTILES

Published by:

INDIAN ROADS CONGRESS

Kama Koti Marg,
Sector-6, R.K. Puram,
New Delhi-110 022

JUNE, 2022

Price: ₹ 400/-
(Plus Packing & Postage)

IRC:SP:129-2022

Guidelines for the Design and Construction of Roads Using Coir Geotextiles

Author's Name

Indian Roads Congress

Published by

Indian Roads Congress

Publisher's Address

Kama Koti Marg, Sector-6, R.K. Puram, New Delhi-110 022

Printer's Details

Dee Kay Printers, 5/37A, Kirti Nagar Indl. Area, New Delhi -110 015

Edition Details

First Published, June, 2022

(All Rights Reserved. No part of this publication shall be reproduced, translated or transmitted in any form or by any means without the permission of the Indian Roads Congress)

CONTENTS

S. No.	Description	Page No.
	Personnel of the Highways Specifications and Standards Committee	i-ii
1.	Introduction	1
2.	Coir and Coir Geotextiles	3
2.1	Coir	3
2.2	Coir Geotextiles	4
2.3	Functions of Coir Geotextile (CGT)	5
2.4	Bio-degradability of CGT	7
2.5	Subgrade Improvement by Application of CGT	7
2.6	Production of CGT	8
2.7	Tight Winding of CGT	8
2.8	Transportation & Handling of CGT	8
2.9	Storage of CGT	8
2.10	Site Handling	8
3.	Pavement Design with Application of CGT	8
3.1	Pavement Composition	8
3.2	Estimation of Pavement Thickness	10
3.3	Pavement Analysis	10
4.	Properties and Selection of Coir Geotextile	14
4.1	Properties of CGT	14
4.2	Selection and Technical Specifications of Coir Geotextiles for Roads	14
5.	Construction Aspects	15
5.1	Installation of Coir Geotextile in Road Construction	15
5.2	Jointing Precautions	18
5.3	Quality Control on Application of Coir Geotextile at Site	18
5.4	Limitations of Coir Geotextile	18
6.	Quality Control Tests for Coir Geotextiles (CGT)	18
6.1	Physical Properties	19
6.2	Mechanical Properties	19
6.3	Hydraulic Properties	20
7.	Application of Coir Geotextiles for Rain Water Erosion Control in Road Embankments	20
7.1	Coir Geotextile	20
7.2	Mechanism of Soil Erosion	20
7.3	Role of Coir Geotextiles in Surface Erosion Control	21
7.4	Selection of Coir Non Woven Composite Geo-Textiles/Coir Stitched Blankets	21
7.5	Installation Method	21
	References	25
	Annexure A	27
	Annexure B	30

LIST OF FIGURES

S.No.	Description	Page No.
Fig. 1	Woven Coir Geotextiles	4
Fig. 2	Separation Function of Coir Geotextile	5
Fig. 3	Filtration Function of Coir Geotextile	6
Fig. 4	Drainage Function of Coir Geotextile	6
Fig. 5	Reinforcement Function of Coir Geotextile	7
Fig. 6	Typical Section of Coir Geotextile Reinforced Flexible Pavement for Low Volume Roads	9
Fig. 7	Three Layer System for Pavement Analysis	11
Fig. 8	Thickness of Granular Layers for 700 gsm Coir Geotextile Reinforced Pavement Sections	12
Fig. 9	Thickness of Granular Layers for 400 gsm Coir Geotextile Reinforced Pavement Sections	13
Fig. 10	Subgrade Clearing before Laying of Coir Geotextile	15
Fig. 11	Laying of Coir Geotextile over Subgrade	17
Fig. 12	Laying & Fixing of Coir Geo-textile to Control Rain Water Erosion	22
Fig. 13	Fixing and Stapling on Slopes	22

LIST OF TABLES

S.No.	Description	Page No.
Table 1	Physical Properties of Coir Fibre	3
Table 2	Requirements of Woven Coir Geotextiles	14
Table 3	Guidance in Selecting the Species of Vegetation	23
Table 4	Grasses Recommended for Soil Moisture Conservation (SMC) and Slope Stabilization	24

ABBREVIATIONS

CGT - Coir Goetextiles

t_g - Thickness of geotextile

w - Width of coir geotextile

k_p - Co-efficient of normal permeability

i - Hydraulic gradient

θ - Hydraulic transmissivity

**PERSONNEL OF THE HIGHWAYS SPECIFICATIONS
AND STANDARDS COMMITTEE**
(As on 12.09.2020 and continued on 19.09.2020 & 03.10.2020)

1	Pandey, I.K. (Convenor)	Director General (Road Development) & Special Secretary to Govt. of India, Ministry of Road Transport and Highways, New Delhi
2	Balakrishna, Y. (Co-Convenor)	Additional Director General, Ministry of Road Transport and Highways, New Delhi
3	Kumar, Sanjeev (Member-Secretary)	Chief Engineer (R) S, R & T, Ministry of Road Transport and Highways, New Delhi

Members

4	Behera, Bijan Kumar	Engineer-in-Chief (Civil) (Retd.), Odisha
5	Bose, Dr. Sunil	Head (Retd.), FP Division, Central Road Research Institute, New Delhi
6	Chandra, Dr. Satish	Director, Central Road Research Institute, New Delhi
7	Gupta, D.P.	DG(RD) & AS (Retd.), Ministry of Surface Transport, New Delhi
8	Jain, R.K.	Chief Engineer (Retd.), PWD Haryana
9	Kapila, K.K.	Chairman & Managing Director, ICT Pvt. Ltd., New Delhi
10	Kukrety, B.P.	Associate Director, CEG Ltd., New Delhi
11	Kumar, Dr. Mahesh	Engineer-in-Chief (Retd.), PWD (B&R) Haryana
12	Lal, Chaman	Engineer-in-Chief (Retd.), PWD Haryana
13	Mina, H.L.	Secretary (Retd.), PWD Rajasthan
14	Nashikkar, J.T.	Secretary (Retd.), PWD Maharashtra
15	Nirmal, S.K.	Additional Director General, Ministry of Road Transport and Highways & Secretary General, Indian Roads Congress, New Delhi
16	Parida, Prof. (Dr.) M.	Deputy Director, Indian Institute of Technology, Roorkee
17	Patel, S.I.	Secretary (Retd.), PWD (Roads and Buildings) Gujarat
18	Prasad, R. Jai	Engineer-in-Chief (Retd.), PWD & Bangalore Mahanagar Palike, Karnataka
19	Rawat, M.S.	Executive Director, AECOM India Pvt. Ltd.
20	Reddy, Dr. K.S. Krishna	Chief Project Officer, Karnataka State Highways Improvement Project, Karnataka
21	Reddy, I.G.	Engineer-in-Chief (NH, CRF & Buildings), PWD Hyderabad
22	Reddy, Prof. (Dr.) K.S.	Professor, Indian Institute of Technology, Kharagpur
23	Sharma, S.C.	DG(RD) & AS (Retd.), Ministry of Road Transport and Highways, New Delhi (Expired in Feb, 2020)
24	Shrivastava, A.K.	Additional Director General (Retd.), Ministry of Road Transport and Highways, New Delhi
25	Singh, Nirmaljit	DG(RD) & SS (Retd.), Ministry of Road Transport and Highways, New Delhi
26	Sinha, A.V.	DG(RD) & SS (Retd.), Ministry of Road Transport and Highways, New Delhi

27	The Chief Engineer (Basar, Toli)	PWD Arunachal Pradesh
28	The Addl. DGBR (North-West) (Kumar, Anil)	Border Roads Organisation, New Delhi
29	The Director (Tech.) (Pradhan, B.C.)	National Rural Infrastructure Development Agency, New Delhi
30	The General Manager (Projects) (Retd.) (Kaul, Satish)	National Highways and Infrastructure Development Corporation Ltd., New Delhi
31	The JICA Expert (Kitayama, Michiya)	Japan International Cooperation Agency, New Delhi
32	The Member (Projects) (Pandey, R.K.)	National Highways Authority of India, New Delhi
33	The Professor (Chakroborty, Dr. Partha)	Indian Institute of Technology, Kanpur
34	The Secretary (Vasava, S.B.)	Roads and Buildings Department, Gujarat
35	The Secretary (Roads) (Joshi, C.P.)	PWD Maharashtra
36	The Secretary (Tech.) (Tickoo, Bimal) (Retd.)	Roads and Buildings Department, Jammu & Kashmir
37	The Special Director General (Retd.) (Bansal, M.C.)	CPWD, Nirman Bhawan, New Delhi
38	Venkatesha, M.C.	Consultant
39	Wasson, Ashok	Member (Tech.) (Retd.), National Highways Authority of India, New Delhi

Corresponding Members

1	Jaigopal, R.K.	MD, Struct Geotech Research Laboratories (P) Ltd., Bengaluru
2	Justo, Prof. (Dr.) C.E.G.	Professor (Retd.), Emeritus (<i>Expired in June, 2019</i>)
3	Veeraragavan, Prof. (Dr.) A.	Professor, Indian Institute of Technology, Madras

Ex-Officio Members

1	President, Indian Roads Congress	(Joshi, C.P.), Secretary (Roads), PWD Maharashtra
2	Director General (Road Development) & Special Secretary to Govt. of India	(Pandey, I.K.), Ministry of Road Transport and Highways, New Delhi
3	Secretary General Indian Roads Congress	(Nirmal, Sanjay Kumar), Additional Director General, Ministry of Road Transport and Highways, New Delhi

GUIDELINES FOR THE DESIGN AND CONSTRUCTION OF ROADS USING COIR GEOTEXTILES

1. INTRODUCTION

Geotextiles are permeable materials applied in soil to improve its engineering performance. Geotextiles may be either man-made (loosely called synthetic) or natural. Man-made Geotextiles are made of artificial fibres like polypropylene, polyethylene and some other petrochemical derivatives. Natural Geotextiles, on the other hand, are made out of natural fibres like coir, jute, sisal. Coir Geotextile (CGT) is a natural technical textile. The efficacy of CGT in erosion control has already been established through laboratory studies, and extensive successful field applications in India and in other parts of the world. It has been observed that CGT, when applied at the interface of sub-grade and sub-base, enhances the load bearing capacity of subgrade soil by performing the concurrent functions of separation, filtration, drainage and initial reinforcement within one or two season cycles.

India is one of the major stakeholders of coir in the world. Hence, the use of CGT will intensify the utilization of the country-resource within its own geographical area and environment. The Coir Board, as a technology provider of CGT has been conducting promotional activities to create awareness on effectiveness of CGT among the road engineers throughout the country in association with Central Coir Research Institute (CCRI), Alappuzha, Kerala and various IITs, NITs and Engineering Colleges. As a result, use of CGT in road construction works has been increasing, but at a very slow pace.

Coir geotextile has been successfully utilized for many applications such as slope protection, drainage and as a reinforcement material. It has been extensively used in large scale field projects in India as a reinforcement in rural roads (Sridhar and Kumar, 2018; Sayida et al., 2019; Rao et al., 2020). Though the coir geotextile has a disadvantage of decomposition with respect to time, it can contribute to a long-lasting infield service life of 4-10 years in case of geotechnical applications (Hejazi et al., 2012) due to its high lignin content. During the course of its infield service life, the coir geotextile enhances the consolidation process in the subgrade and make its presence unnecessary in the long term (Subaida et al., 2009). Field tests conducted on coir geotextile reinforced test track by Sayida et al. (2019) revealed that there were changes in the characteristic deflection and Dynamic Cone Penetration (DCP) indices; about 50% improvement in field CBR values were obtained for the reinforced pavement. Benkelman Beam Deflection (BBD) test conducted by them on coir geotextile reinforced and unreinforced sections of pavement clearly indicated the improved performance of the coir geotextile reinforced pavement. Large scale field studies on coir geotextile reinforced rural roads, followed by numerical analysis have proved that reduction of aggregate layer thickness is possible by introducing coir geotextile as a reinforcement at the interface of subgrade and sub-base (Visvanathan et al., 2020). Laboratory plate load test experiments and the finite element analysis conducted by Anusudha et al. (2020) has proved that reduction of pavement layer thickness is possible when coir geotextile is used as a reinforcement at the interface of subgrade and subbase layer. An experimental study conducted by Tiwari and Satyam (2020) on lime treated coir geotextile to stabilize expansive soil reaffirmed that the improved property of the reinforced expansive soil subgrade could effectively reduce the thickness

of the granular layers of the pavement. From the above-mentioned studies, it is evident that coir geotextiles can appreciably enhance the strength and stiffness of a subgrade. However, a well-established design with proven field results is mandatory before the deployment of pavement sections with coir geotextile reinforcement.

The task of preparation of these Guidelines was taken up by Rural Roads Committee (H-5) during the tenure 2018-20. A subgroup consisting of Dr. Samson Mathew, Chairman (NIT, Tiruchirappalli), Dr. MVLR Anjaneyulu (NIT, Calicut), Dr. Sheela Evangeline (CoE, Thiruvananthapuram), Dr. Anita Das (Coir Board, Alappuzha), Dr. K. Balan, (RIET, Nagaroor), Shri A.V. Rajesh (SRRDA, Chennai) was constituted to prepare the draft. The subgroup submitted its draft to IRC in November, 2018. The subgroup was being coordinated by Dr. I.K.Pateriya (NRIDA, Delhi). Dr. A. Veeraragavan (IIT, Madras), was requested to attend all the meetings as a special invitee and review the document. H-5 Committee acknowledges the contribution of Dr. V. Sunitha (NIT, Tiruchirappalli), Mrs. Sumi Sebastian (Coir Board, Alappuzha) and Ms. Anusudha Visvanathan (NIT, Tiruchirappalli) in preparation of this document. The draft was discussed in various meetings of H-5 Committee and a detailed presentation was held on 15.05.2020. The draft was further updated based on the comments of members and all the comments of members were discussed once again in meeting of H-5 Committee held on 01.09.2020. The draft was then approved for placing before the Highways Specifications and Standards Committee (HSS). HSS approved the draft in its meeting held on 12.09.2020 and continued on 19.09.2020 & 03.10.2020. The Executive Committee (EC) in its meeting held on 18.02.2021 approved the draft document for placing before the Council. The draft was finally approved by IRC Council in its Mid-Term Council Meeting held on 20th – 21st February, 2021.

The composition of Rural Roads Committee (H-5) is given below:

Gupta, D.P.		Convenor
Pateriya, Dr. I.K.		Co-Convenor
Rajesh, A.V.		Member-Secretary

Members

Agarwal, Pankaj	Kumar, Dr. Praveen
Aggarwal, Prof. Praveen	Parameswaran, Dr. Lakshmy
Banerjee, A.K.	Pradhan, B.C.
Das, A.K.	Reddy, Dr. M.A.
Debbarma, Rajib	Sahoo, Dr. U.C.
Gupta, M.C.	Saikia, K.K.
Gupta, M.K.	Sarkar, Dr. A.K.
Hiremath, Mahesh M.	Sharma, S.C. (<i>Expired in Feb, 2020</i>)
Jawaid, Dr. S.M. Ali	Srivastava, K.K.
Joshi, Dr. G.J.	Thube, Dr. D.T.
Kumar, Dr. Ashok	

Corresponding Members

Bongirwar, P.L.	Justo, Prof. C.E.G. (<i>Expired in June, 2019</i>)
Dhinsa, Jaswant Singh	Sharan, G.

Ex-Officio Members

President, Indian Roads Congress	(Joshi, C.P.), Secretary (Roads), PWD Maharashtra
Director General (Road Development) & Special Secretary to Govt. of India	(Pandey, I.K.), Ministry of Road Transport & Highways
Secretary General, Indian Roads Congress	(Nirmal, Sanjay Kumar), Additional Director General, Ministry of Road Transport & Highways

2. COIR AND COIR GEOTEXTILES

2.1 Coir

Coir is a natural fibre extracted from the coconut husk. Technically coir is the fibrous material found between the hard, internal shell and the outer coat of a coconut. The individual fibre cells are narrow and hollow, with thick walls made of cellulose. The major components of coir fibre are Lignin (45.84%), Cellulose (43.44%), Hemicellulose (0.25%), Pectin and other compounds (3%), Water soluble contents (5.25%) and Ash (2.22%). Coir is the hardest fibre in comparison with other natural fibres because of its high lignin content. Coir fibre is in great demand because of its toughness, strength, rot resistance, durability, natural resilience, porous, hygroscopic, biodegradable, renewable, recyclable, versatile etc. The surface of the coir fibre is rather smooth with little adhering segments. When viewed under a microscope, it is seen that the fibre is circular or oval-shaped in cross section with a hollow central lumen. The presence of large empty space in the fibre accounts for its buoyancy. The extensibility and tensile modulus of the cells of coir fibres are related to the spiral angle of the microfibrillar structure. Therefore, coir fibre is able to withstand sudden loading better than other hard fibres. Coir has low density due to its porosity; about a third of the fibre is filled by air to give it the property of springiness (resilience). Further lightness and porosity make it more buoyant when immersed in water, resisting its penetration for a long time. Coir being heavily lignified compared to the bast fibres like jute. When soaked in water for some time, the filaments swell in lateral directions. There is little or no longitudinal swelling.

Coir fibre has a high aspect ratio, high strength to weight ratio, good insulation properties and is low in energy conversion. Coir fibres are much coarser than most of the other natural fibres and the extent of elongation of coir is not approached by any of the bast fibres. Some salient physical properties of coir are given in **Table 1**.

Table 1 Physical Properties of Coir Fibre

Physical Property	Value
Breaking load (kg), <i>Min</i>	0.45
Tenacity (g/tex), <i>Min</i>	10.00
Extension at break (%), <i>Min</i>	29.13
Flexural rigidity (dynes.sq.cm.), <i>Min</i>	200.00
Density (g/cc), <i>Min</i>	1.40
Moisture regain at 65% R.H (%), <i>Min</i>	10.50

Physical Property*	Value
Specific gravity, <i>Min</i>	1.15
Fibre diameter (mm), <i>Min</i>	0.1 to 0.8
Length of individual fibre (mm), <i>Min</i>	Up to 250
Water absorption, <i>Min</i>	40%
Thermal conductivity (cal/hour/sq.m), <i>Min</i>	Between 4.3 to 10.4
Coefficient of thermal expansion, <i>Min</i>	$6.4 \times 10^{-6} / ^\circ\text{C}$
Young's Modulus (mean value)	4.5 GN / sq.m
Rigidity Modulus (mean value)	0.189 N / sq.m
Transverse Modulus (mean value)	6.086 GN / sq.m

* The test methods comply with "Indian Coir: A reference book"

2.2 Coir Geotextiles

Coir Geotextiles (Coir Bhoovastra) are permeable fabrics made from coir fibre extracted from coconut husk either by natural retting or by mechanical process. It is a woven fabric of two treadle in construction, made from coir yarn in which the warp and weft strands are positioned at a distance to get a mesh (net) effect as shown in **Fig. 1**. Non-woven coir geotextiles consist of a stitched blanket with thin PP net on top and bottom and stitched with Jute or PP yarns.



Fig. 1 Woven Coir Geotextiles

Coir geotextiles are used for surfacial erosion control on slopes through vegetation, as well as protection of banks of river, canal and lakes, road and railway embankment and reinforcement of mud wall of stream, bunds, farm and fishponds against erosion and other applications involving separation and filtration. It controls the soil erosion by acting as a ground cover or mulch. As a mulch, coir geo textiles provide ideal environment for the seeds to germinate and for healthy

growth of seedling by regulation of soil humidity, temperature, controlling weeds, and by protection from direct sunlight and rain.

2.3 Functions of Coir Geotextile (CGT)

A properly designed Coir Geotextile is supposed to perform the following functions usually in conjunction, in different application areas related to civil engineering:

Separation

Filtration & Drainage

Reinforcement

2.3.1 Separation

This is the principle function of coir geotextile when placed beneath the aggregate layer of an unpaved road. The coir geotextile prevents intermixing of aggregate and underlying subgrade soil as shown in **Fig. 2**. The separation function that a geotextile provides keeps the subgrade soils and aggregate layer intact, allowing the aggregate layer to maintain its designed thickness over the life of the roadway. Coir geotextile tends to cause the whole layer to act together in the manner of a flexible beam and spreads the load over a larger area. This separation and confinement plus additional strength gained by frictional interlock between the aggregate and coir geotextile, help maintain reduced stress on the subgrade, and thereby increase the load bearing capacity of the structural section.

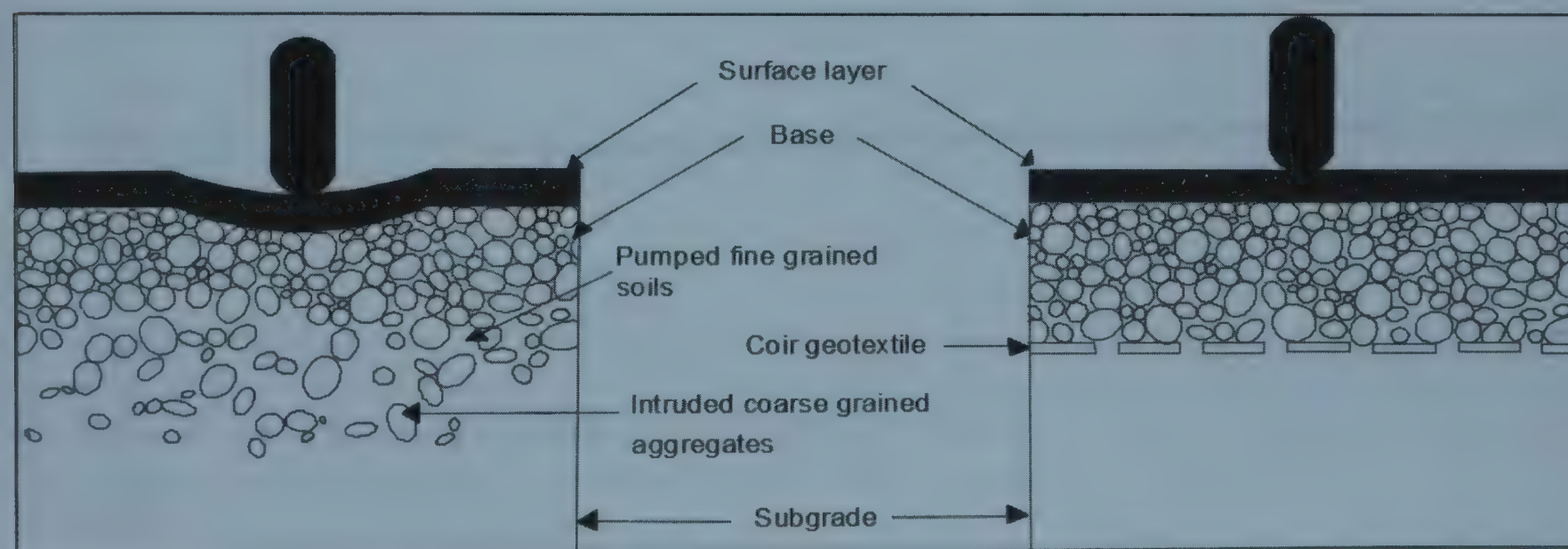


Fig. 2 Separation Function of Coir Geotextile

2.3.2 Filtration & Drainage

The coir geotextile will also function as a filtration and drainage medium in the presence of wet or saturated soils. Under dynamic loading, high pore pressure creates soil slurry that pumps upward against the fabric. The coir geotextile acts as a filter and screens out fines from contaminating the aggregate layer, while allowing water to drain freely through the aggregate or through the plain of the coir geotextile. It thus aids the accelerated consolidation of the subgrade. The filtration and drainage functions of a coir geotextile are shown in **Fig. 3 & 4**.

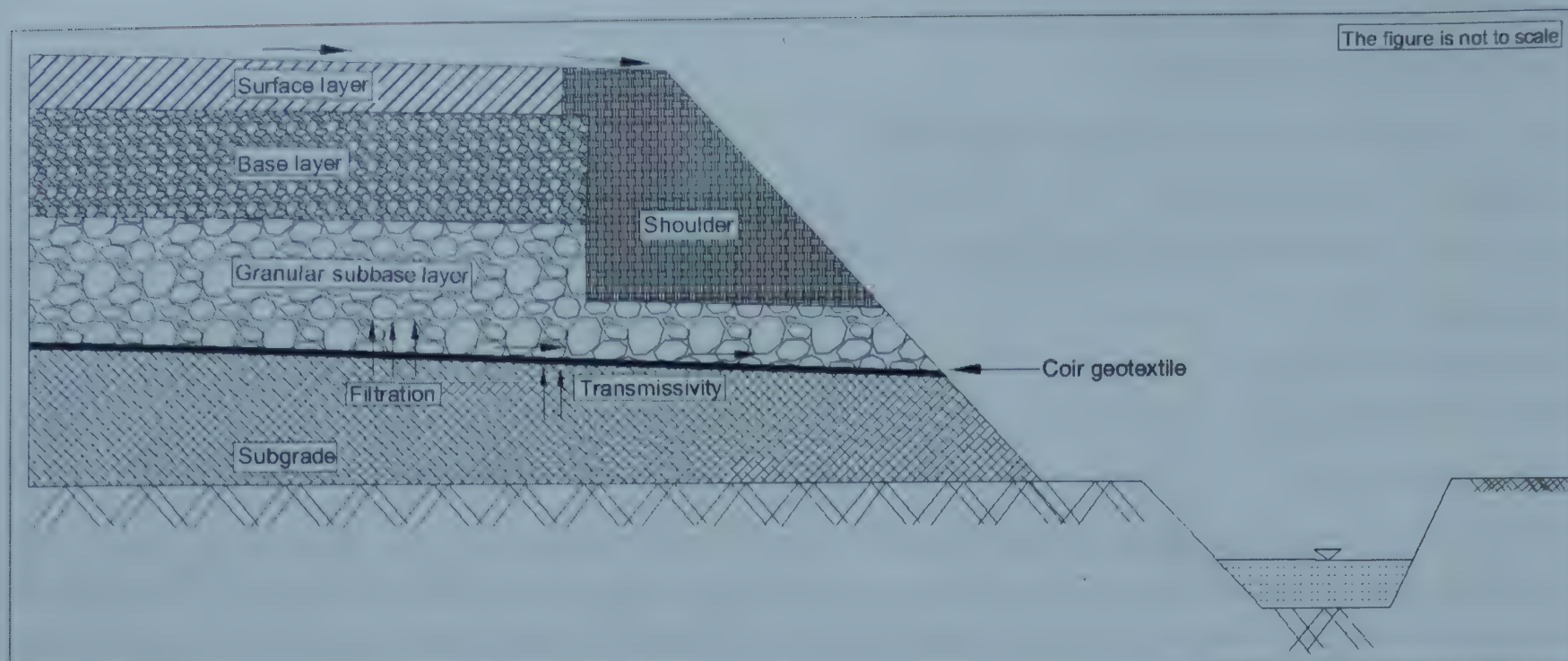


Fig. 3 Filtration Function of Coir Geotextile

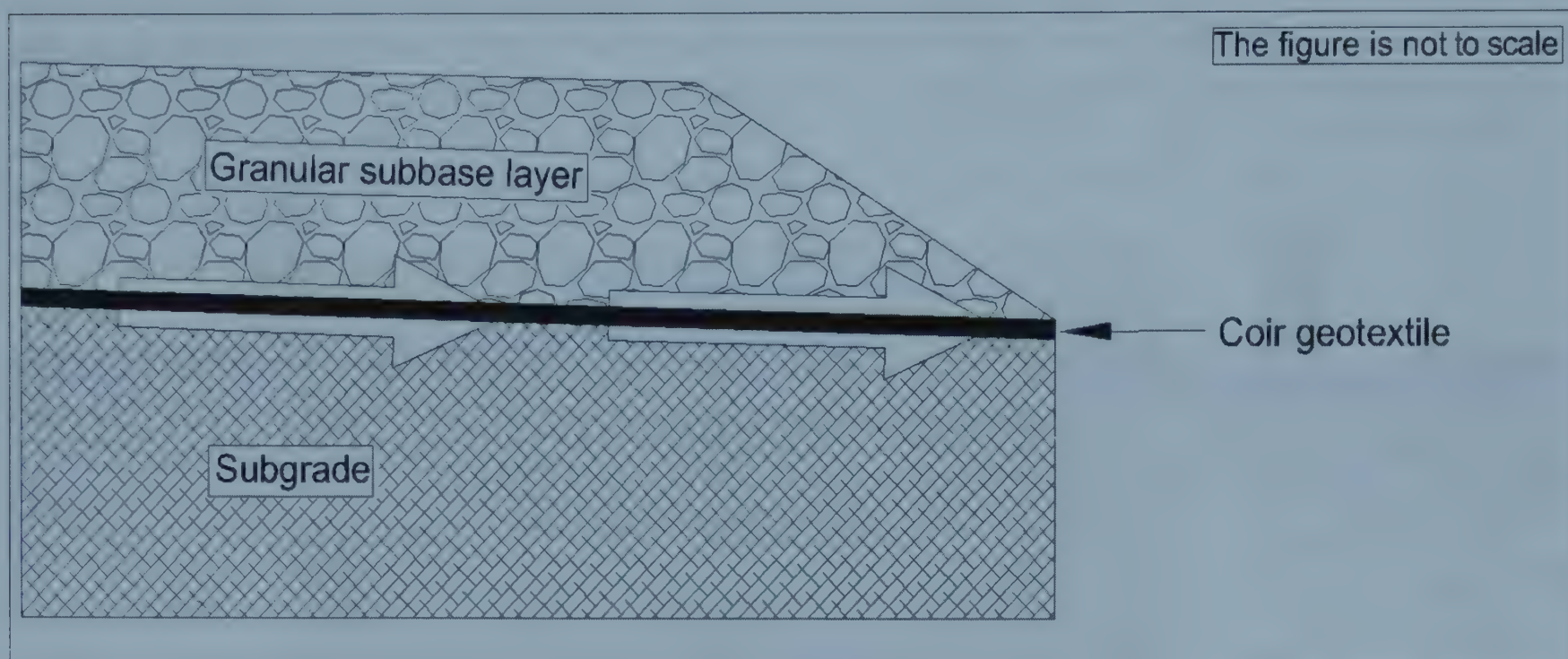


Fig. 4 Drainage Function of Coir Geotextile

2.3.3 Reinforcement

The two principal mechanisms of the coir geotextile are to confine and restrain movement of the granular, structural layer and the so called membrane effect whereby a fabric that develops high tensile strength under load can induce a vertical stress upward. This aids the granular layer to support vehicular loading while reducing the magnitude of the stress imposed upon the sub-grade. Coir geotextile will ensure that no intermixing takes place at this level and the effective depth of the pavement remains intact. The coir geotextile is useful for soft sub-grades with soaked CBR value of 2% as per Clause 6.4 of IS 15871.

The various functions of the geotextile embedded in a pavement is shown in **Fig. 5**.

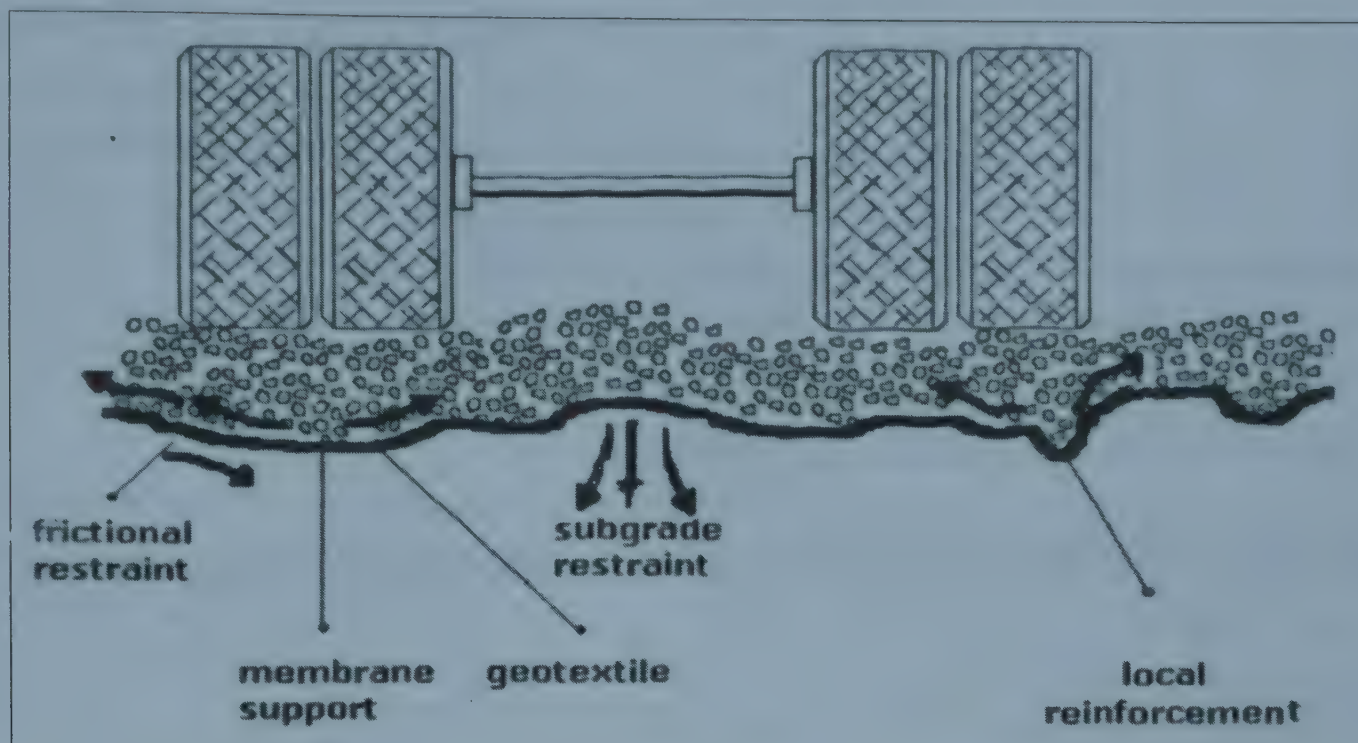


Fig. 5 Reinforcement Function of Coir Geotextile

2.4 Bio-degradability of CGT

Studies have proven that the life of coir geotextile under compacted soil is above five years. Samples have been excavated undisturbed from the compacted soil even after six years as part of the studies conducted on coir geotextile reinforced roads.

The potential of natural geotextiles lies in areas of short to medium term applications, with high performance and a life span of 1.5 to 3 years. Coir fibre is coarse, rigid, strong and has slow rate of degradation. The slow rate of degradation is attributed to the high lignin content of the coir fibre. The high content of lignin in coir fibre, bestows strength to the coir geotextile, which remains undisturbed and embedded in the soil.

Biodegradation of coir geotextiles is a very slow process in comparison to the other natural geotextiles like jute and sisal. The acidic phenolic materials leached out from the coir prevent the indigenous micro flora from attacking it. With the passage of time, biodegradation sets in with the enrichment of the phenolic precursors leached out into the soil environment.

The life expectancy of the natural geo textiles depends on the soil structure and composition; climate conditions, UV radiation aspects, rainfall at site, temperatures and type of applications. Coir geotextiles degrade at a faster rate in sand with high organic content, whereas it degrades at a very slow rate in clay with high organic content. As the depth of embedment in soil increases, the degradation of coir geotextile decreases.

2.5 Subgrade Improvement by Application of CGT

The regions of extremely low load bearing capacity soil are reliant on reinforcement above it to avoid failure of the constructed facilities due to the anticipated loads. Improvement of subgrade has to be done for weak soils. In this context, placing the geotextile over the subgrade could improve the performance of the pavement by mobilizing its strength through improved load bearing capacity by the membrane effect and lateral restraint behaviour. Embedding coir geotextile reinforcement at the interface of subgrade and granular layers of a pavement can increase the lateral restraint by confining the local soil underneath and aggregates overlying, with

a consequent gain in restricting both vertical and lateral deformations. It helps in arresting the lateral movement of the local soil and the granular materials by friction and interlocking, thereby increasing the modulus of the structural layers of the pavement. The magnitude of vertical stresses underneath the pavement diminishes with increase in the modulus of the pavement layers. As a result, significant reduction in thickness of granular layers of a pavement is possible. In addition, the functions of the geotextiles like separation, filtration and drainage helps in prolonging the service life of the pavement.

2.6 Production of CGT

The coir geotextiles are manufactured by hand looms, semi-automatic looms and fully automatic power looms. Woven coir geotextile matting are of two-treadle weave in construction, with the warp and weft strands positioned at a distance to get mesh effect. Coir Bhoovastra (Coir Geotextile) is a net fabric from coir fibre. The nettings are normally produced out of 2 ply coir yarn, and in rolls of 50 metre length and 1 to 4 metre width.

A non-woven blanket with coir fibre is manufactured by laying the fibres randomly in a bed by a laying process, supported by light synthetic mesh on top and bottom and by stitching with either synthetic or jute yarns, to keep the fibres in position.

2.7 Tight Winding of CGT

To decrease the volume of rolls during transportation, the rolls are tightly wound under tension by mechanical means. The number of rolls transported in a container can be increased by this tight winding; additional 40% to 50% rolls can be accommodated, depending upon the variety of coir geotextiles and thereby reducing the cost of transportation, handling and storage.

2.8 Transportation & Handling of CGT

Coir Geotextiles in the form of rolls can be easily handled and transported. But care is to be taken to keep them free from moisture (being hygroscopic) and fire hazards.

2.9 Storage of CGT

During storage, the geotextiles must be covered to avoid direct contact with atmosphere. The best practice is to cover them with tarpaulin sheets on all sides. Spreading of slaked lime before placing the coir geotextiles can prevent the attack of termites on coir geotextiles.

2.10 Site Handling

As already stated, coir geotextile rolls should be provided with a protective wrapping. It should be kept above the ground and should be covered with a tarpaulin or a plastic sheet. Exposure of coir geotextile to moisture/water may pose handling problems, as coir geotextile can absorb water. Handling wet coir geotextile becomes more difficult than handling moisture free coir geotextile.

3. PAVEMENT DESIGN WITH APPLICATION OF CGT

3.1 Pavement Composition

The coir geotextile reinforced low volume road consists of the following layers, as shown in **Fig. 6** given below.

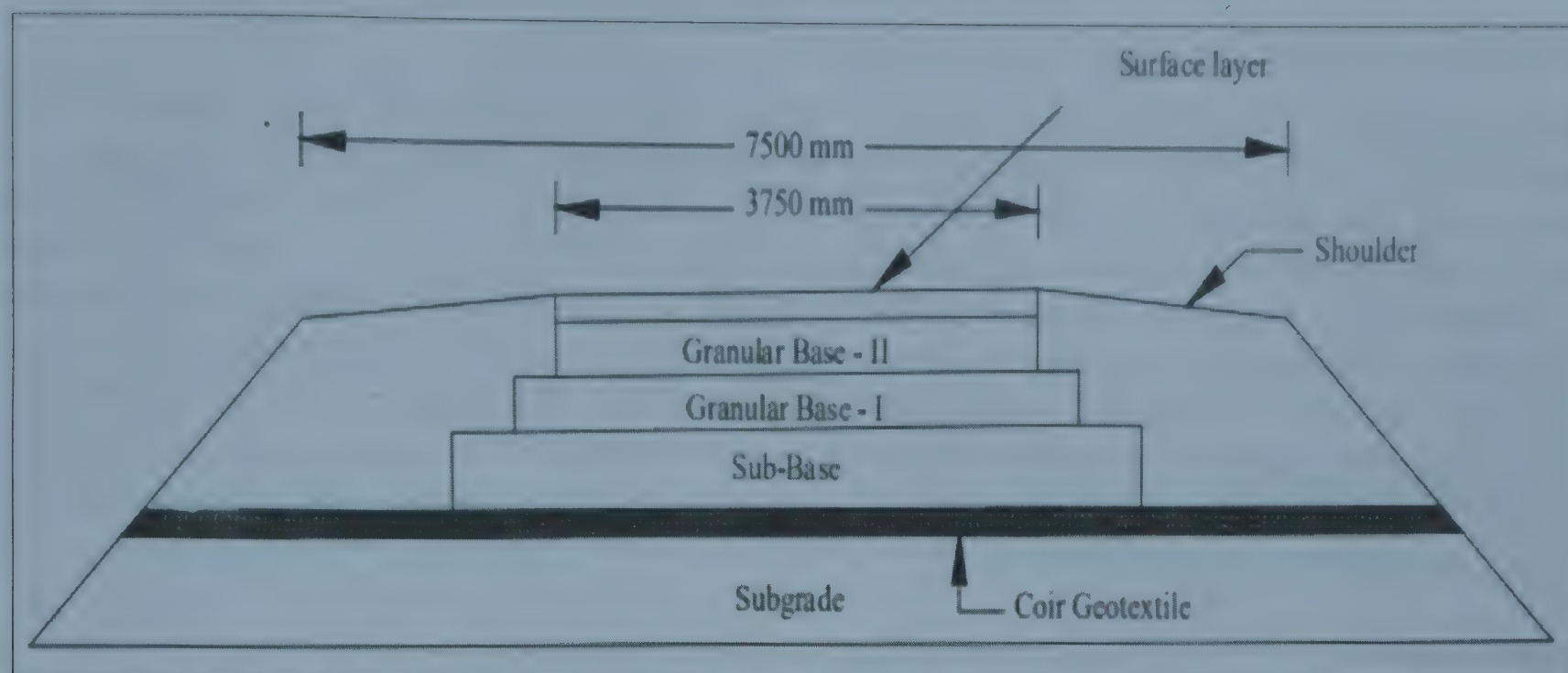


Fig. 6 Typical Section of Coir Geotextile Reinforced Flexible Pavement for Low Volume Roads

3.1.1 Subgrade

The subgrade is the foundation layer of a pavement, which is also called as formation level. Prior to the construction of other layers of pavement, subgrade is usually overlaid with borrow soil or modified soil when the parent soil of the region is found to be weak. But by embedding a reinforcing element like coir geotextile over the subgrade, the use of imported soil or modified soil can be avoided, as the geotextile can serve as a surrogate for the improved soil. The subgrade has to be compacted up to the target density before placing the coir geotextile over it.

3.1.2 Coir geotextile

The desired coir geotextile is rolled over the well compacted subgrade upto full roadway-width in case of new construction. If widening is desired for the existing pavement, the geotextile shall be laid to full width of the existing portion. The overlapping of the geotextiles placed side by side along the width of the pavement shall be a minimum of 100 mm and they shall be pegged/tied at regular intervals. It is advised to provide a thin cushion of 10 mm of locally available earth material above the coir geotextile in order to avoid puncturing of the geotextile due to the aggregate layers. The earth material used as cushion material may have a liquid limit value of 20-35 % and Plasticity index < 12% and should be free from organic content. The installation of the woven coir geotextile may be carried out as per Clause 7 of IS 15871.

3.1.3 Sub-base course

The prime function of a sub-base layer is to provide structural support to the pavement. In addition, the sub-base layer maintains the integrity of the pavement layers by minimising the intrusion of fines from the subgrade into the pavement structure. The layer plays a vital role in improving drainage and minimizing frost action damage. Suitable material for granular sub-base course such as natural sand, moorum, gravel, crushed stone, crushed slag, brick metal, kankar and combination thereof, depending upon the grading required as per relevant clauses of the MORD Specifications for Rural Roads, shall be used.

3.1.4 Base course

Base course layer contributes in improving the load supporting capacity of the pavement and distributes the traffic loads from top layers to the sub-base and subgrade layers underneath. For rural roads designed for cumulative ESAL repetitions more than 1,00,000, unbound granular bases which comprise conventional Water Bound Macadam (WBM), Wet Mix Macadam (WMM) or Crusher Run Macadam Base shall be adopted as per relevant clauses of the MORD Specifications for Rural Roads. For rural roads designed for cumulative ESAL repetitions less than 1,00,000, a granular base is recommended, except for a very poor subgrade strength (CBR = 2%) under the traffic categories of 30,000 to < 60,000; and 60,000 to < 1,00,000 ESAL applications and for poor subgrade strength (CBR = 3 to 4%) under the traffic category of 60,000 to < 1,00,000 ESAL applications, as per IRC:SP:72.

3.1.5 Surfacing

Surface course layer is the layer directly in contact with traffic loads. It provides characteristics such as friction, smoothness, drainage etc. For rural roads designed for cumulative ESAL repetitions over 1,00,000, a bituminous surface treatment of 2-coat surface dressing or 20 mm premix carpet is recommended, as per relevant clauses of MORD Specifications for Rural Roads. However, for rural roads designed for ESAL applications less than 1,00,000, a non-bituminous gravel surfacing is recommended as per relevant clause of the MORD Specifications, except for the very poor subgrade strength (CBR = 2%) under traffic categories T_2 and T_3 and for the poor subgrade strength (CBR = 3 to 4%) under traffic category T_3 only, where a bituminous surface treatment has been recommended.

3.2 Estimation of Pavement Thickness

The methodology developed for use of coir geotextile in low volume rural roads follows a mechanistic-empirical approach. The thickness of pavement for low volume roads is estimated considering the elastic moduli of pavement component materials, traffic volume, wheel load and the tire pressure using analysis by software called IITPAVE. Coir geotextiles are found to last for as long four to six years within the soil environment depending on the physical and chemical properties of the soil. When it is used as reinforcement, the coir geotextile can share the load with soil until its degradation, thus increasing the load bearing capacity of the subgrade. The strength of the subgrade soil increases in course of time as the soil undergoes consolidation induced by the traffic loads. After a certain stage, the subgrade may become strong enough to support the loads on its own without the necessity for reinforcement. The design is based on the maximum vertical compressive strain over the subgrade to address the rutting failure.

The design has been done for the following conditions:

Cumulative traffic – $30,000 \leq \text{ESAL} \leq 20,00,000$

Subgrade strength – $2\% \leq \text{CBR} \leq 6\%$

Bio-degradability of coir geotextile with respect to time do not cause any hindrance

3.3 Pavement Analysis

The analysis has been carried out considering the pavement to be a three layer system as shown in the **Fig.7** below.

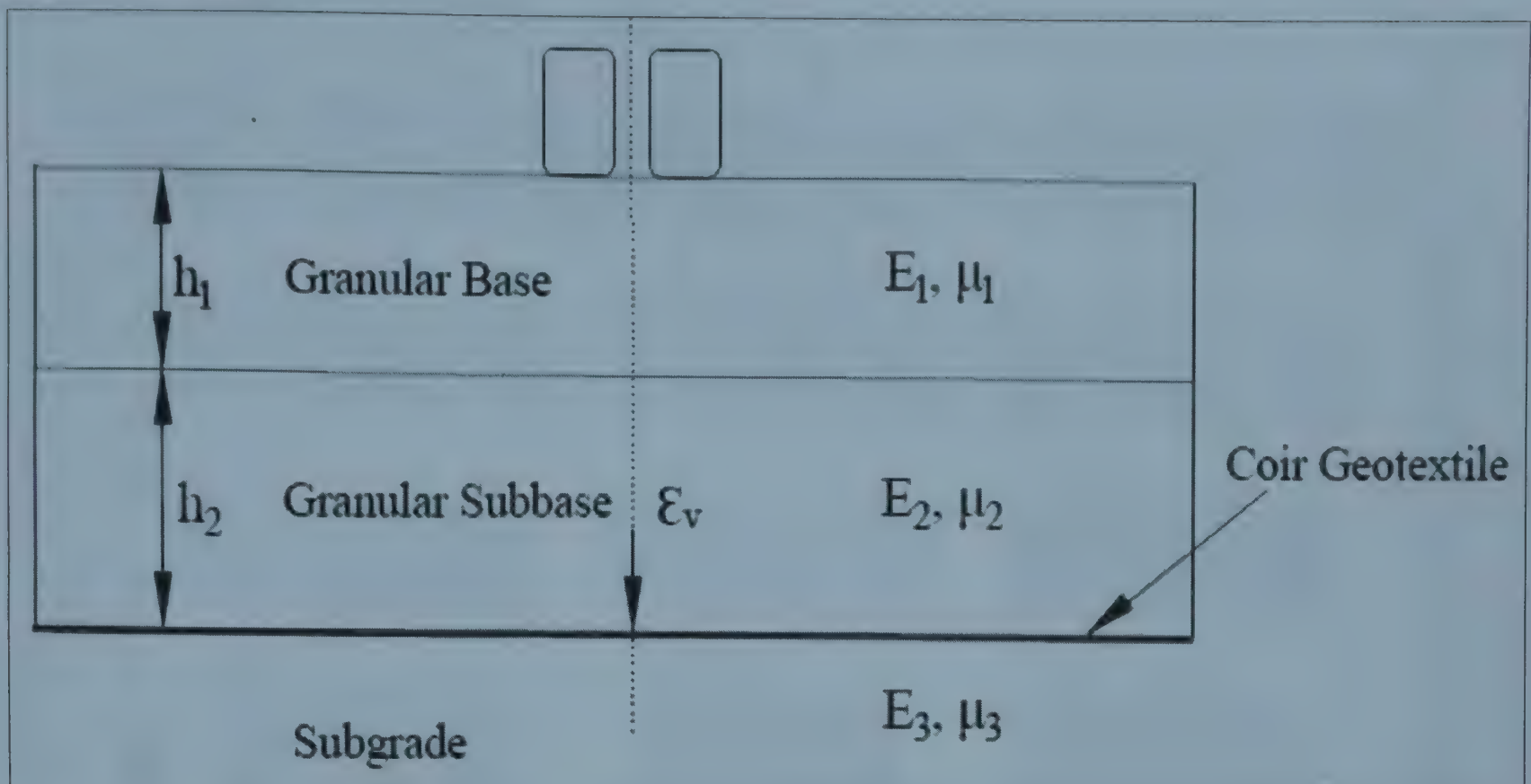


Fig. 7 Three Layer System for Pavement Analysis

The pavement sections suggested in the IRC:SP:72 for different CBR values of subgrade and different traffic conditions were analysed using IITPAVE. The structure was subjected to load from single axle with dual tyre of a truck of 80 kN distributed over a circular area of radius 0.15 m. Linear elastic analysis was carried out, assuming an average contact pressure of 560 kPa. The elastic modulus of the coir geotextile reinforced subgrade determined from the field tests conducted on the coir geotextile reinforced test tracks (18 Nos) located in seven districts of Tamil Nadu, is used for analysis. The design has been worked out for two different coir geotextiles possessing mass density of 700 gsm and 400 gsm and is illustrated in the design example given in the **Annexure A**.

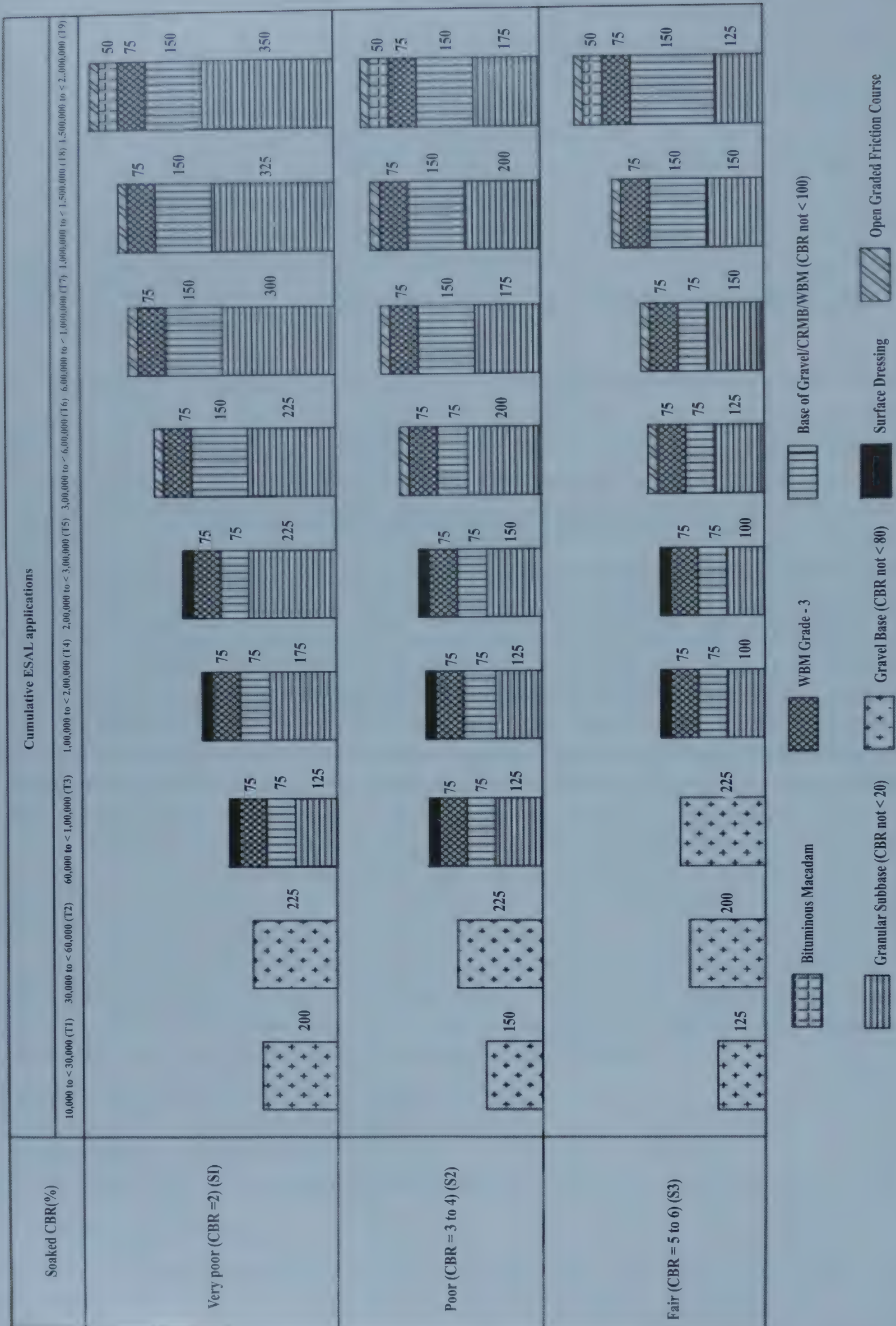


Fig. 8 Thickness of Granular Layers for 700 gsm Coir Geotextile Reinforced Pavement Sections

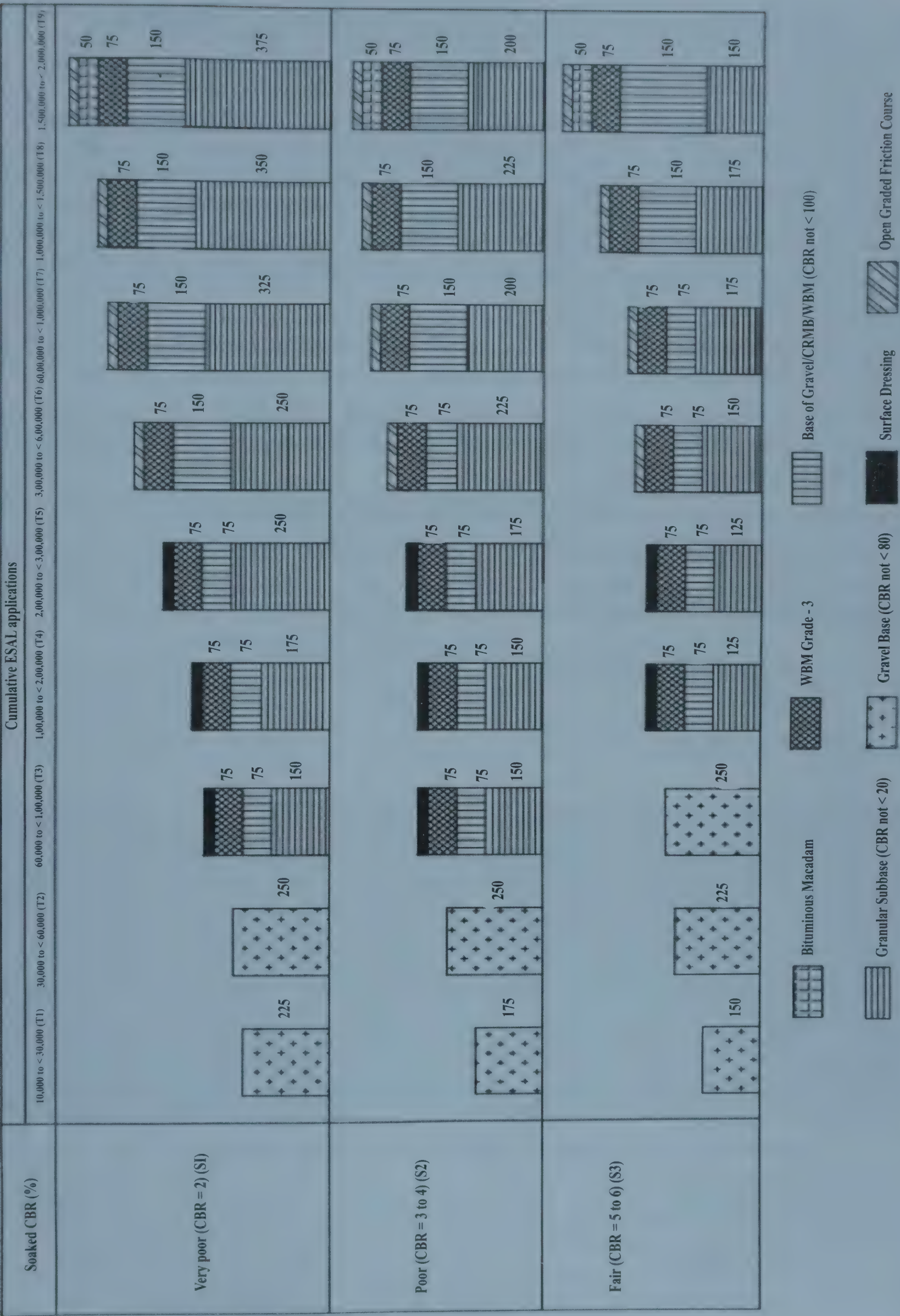


Fig. 9 Thickness of Granular Layers for 400 gsm Coir Geotextile Reinforced Pavement Sections

4. PROPERTIES AND SELECTION OF COIR GEOTEXTILE

4.1 Properties of CGT

Selection of coir geotextile is essentially an empirical exercise supported by practical experience. Retention is the governing criterion of any geotextile, including coir geotextile, in case of road construction, along with tensile strength. Finalization of the porometric features of coir geotextile in relation to the grain size distribution of subgrade soil is a must and most essential. It has also been observed in field applications that fulfilment of retention criterion concurrently achieves the desired value of permittivity, in relation to the practical drainage interaction of soil-subgrade and coir geotextile.

Requirements of Tensile strength of CGT: Tensile strength of woven CGT tested as per IS 16635 or ASTM D4595 shall be as specified in **Table 2**.

Requirements of Porometry of CGT: The design of CGT is based on the parameters that determine the opening size of CGT from functional stand point tested as per IS 15868 (parts 1 to 6) or ASTM D4751 as indicated in **Table 2**.

4.2 Selection and Technical Specifications of Coir Geotextiles for Roads

The choice of CGT basically depends on the type of pavement to be protected. The overall requirement of woven coir geotextiles to be used in construction of low volume rural roads should meet the specifications mentioned in Table 1 of IS 15869 and **Table 2** given below.

Table 2 Requirements of Woven Coir Geotextiles

Sl. No	Characteristic	Grade			Method of Test Ref to IS
		I	II	III	
1.	Mass per unit area, g/m^2 , <i>Min</i>	400	700	900	IS 15868 (Parts 1 to 6)
2.	Width, cm, <i>Min</i>	100.0 or as required	100.0 or as required	100.0 or as required	IS 12503 (Parts 1 to 6)
3.	Length, m	50 or as required	50 or as required	50 or as required	IS 12503 (Parts 1 to 6)
4.	Thickness at 2 kPa, mm, <i>Min</i>	6.5	6.5	6.5	IS 15868 (Parts 1 to 6)
5.	Ends (warp), runnage	180	150	210	IS 12503 (Part 1 to 6)
6.	Picks (weft), runnage	160	160	250	IS 12503 (Part 1 to 6)
7.	Break load, dry (kN/m), <i>Min</i> a) Machine direction	7.0	8.5	15.0	IS 16635
	b) Cross machine direction	4.0	8.0	8.0	
8.	Break load, wet (kN/m), <i>Min</i> a) Machine direction	3.0	7.0	12.5	IS 16635
	b) Cross machine direction	2.0	4.5	5.0	
9.	Peak load, dry (kN/m), <i>Min</i> a) Machine direction	7.5	9.0	18.0	IS 16635
	b) Cross machine direction	4.0	8.0	9.0	

Sl. No	Characteristic	Grade			Method of Test, Ref to IS
		I	II	III	
10.	Peak load, wet (kN/m), <i>Min</i>				IS 16635
	a) Machine direction	3.0	8.5	15.0	
	b) Cross machine direction	2.0	5.5	6.0	
11.	Trapezoidal tearing strength (kN) at 25 mm gauge length, <i>Min</i>				IS 14293
	a) Machine Direction	0.18	0.35	0.50	
	b) Cross Machine Direction	0.15	0.30	0.35	
12.	Mesh size, mm, <i>Min</i>	20.0 × 16.75	7.50 × 7.30	4.2 × 5.1	IS 15868 (Parts 1 to 6)

*The quality requirements are as per IS 15869 - 2020

5. CONSTRUCTION ASPECTS

5.1 Installation of Coir Geotextile in Road Construction

The following sequence should be followed for installation of coir geotextiles as per Clause 7 of IS 15871:

1. Subgrade is to be excavated to the required level, cleared of all foreign materials and compacted to the required density.
2. Vegetation, if any, should be uprooted and the area leveled with earth and rolled.
3. Subgrade should be prepared to the specified camber and profile.
4. Subgrade should be cleared of dry leaves and other materials before laying coir geotextile, as shown in **Fig. 10**.

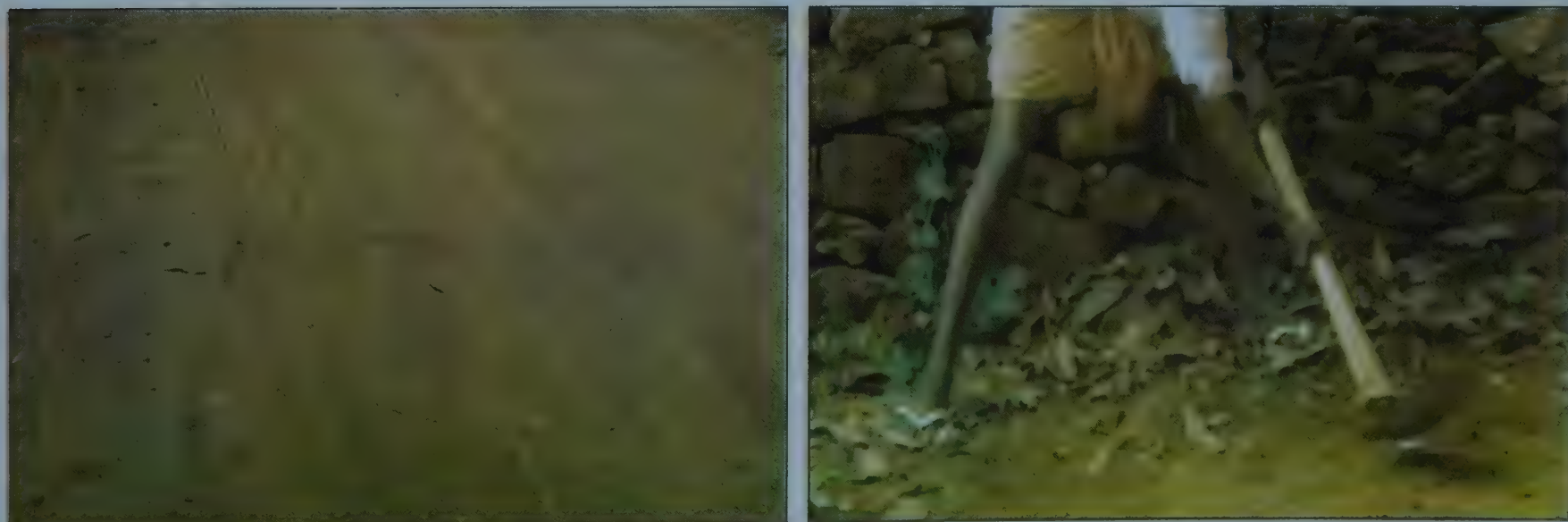


Fig. 10 Subgrade Clearing before Laying of Coir Geotextile

5. **Fig. 11** show the laying of coir geotextile over subgrade. The roll should be unwound a small amount by pushing the roll in the direction of the reinforcement run. The base end of the reinforcement now exposed should be folded and secured by weighting or pinning it to the formation. When the roll is completely unwound, the free end of the reinforcement should be hand tightened and secured by weighting or pinning.



a) Keep the coir geotextiles adjacent and find out the overlap that can be given. Ensure a minimum overlap of 10 cm.



b) Roll out first roll of geotextile with one of the road edges as reference.



c) Roll out slowly to ensure proper positioning and drapability so that the geotextile touches the subgrade layer at all points. Remove the wrinkles after unrolling each roll by gently pulling the ends.



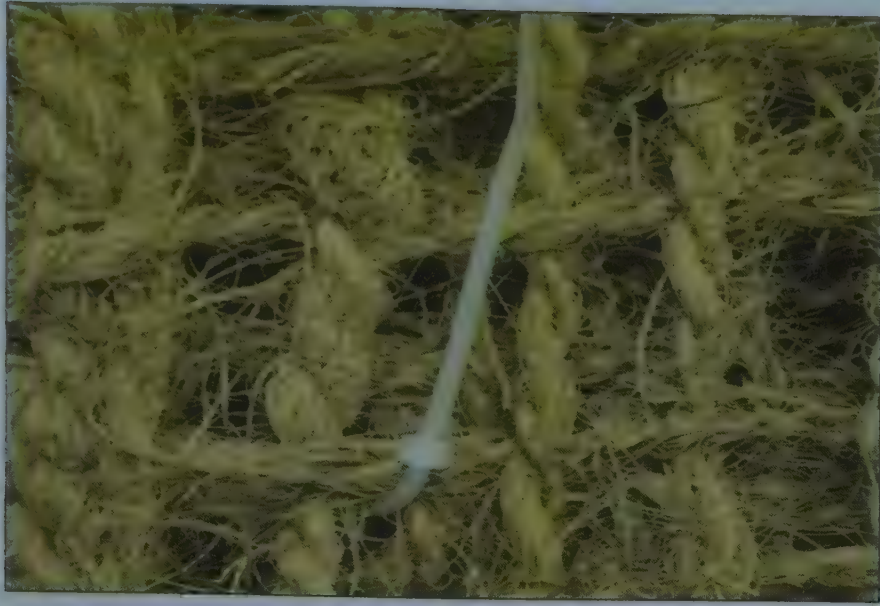
d) Roll out the second and successive rolls of coir geotextile while maintaining overlap, a minimum of 10 cm.



e) Fix the roll at ends to the subgrade.



f) Fix the roll to the subgrade by using U clamps at one metre spacing.



g) Fasten/tie adjacent rolls using Cable tie/suitable means at a spacing of minimum one metre

h) View of Coir geotextile laid over subgrade



i) Coir geotextiles at curves

Fig. 11 Laying of Coir Geotextile over Subgrade

6. At curves, coir geotextiles should be folded or cut and overlapped in the direction of the turn. Folds in coir geotextile should be tied/stapled at an interval of 300 mm in curves.
Before covering up the CGT, its condition should be assessed for any construction/ installation damage. Torn/damaged portions may be covered by pieces of CGT and duly stapled/tied on all sides preferably at an interval of 300 mm. The extent of overlap should be such as to fully cover the damage/torn portion plus at least 75 mm beyond on all sides.
7. The locally available/marginal materials which do not affect the properties of the coir geotextiles can be used along with coir geotextiles.
8. The first layer of material in the subbase or base course with grading as per relevant MoRD specifications should be spread as given below.
 - i) No traffic, including construction vehicles, should be allowed directly on coir geotextile.
 - ii) Bring the tipper lorry with material to the beginning of coir geotextile.
 - iii) Dump the material on geotextile while ensuring that tipper lorry is not coming onto the coir geotextile.
 - iv) Spread the dumped material using excavator bucket or manually.

- v) Bring the tipper lorry with material upto the end of spread material, spread the material manually or using excavator.
 - vi) Check along the edges so that edge lines clearly formed.
9. Other layers of pavement may be constructed as per relevant MoRD guidelines.
10. Often the sub-surface water is drained through the geotextile to the shoulders of a carriageway. In such cases, shoulder drains are required to be constructed either beneath the edge of the shoulder or immediately adjacent to its edge. In the event of existence of black cotton soil or expansive clay, porous drain pipes may also be inserted within the shoulder drain to augment drainage-efficiency.

5.2 Jointing Precautions

Before jointing, the edges of the adjacent coir geotextiles must be adjusted to make it overlap a certain broadband (preferably 100 mm), and it is flat and free of wrinkles. Pegs should not be used to staple the coir geotextile, as it may damage the geotextile. Jointing has to be done as per the instructions given in clause 3.1.2.

5.3 Quality Control on Application of Coir Geotextile at Site

The coir geotextile certified under Coir Mark Scheme of Coir Board only shall be used for construction. The guidelines proposes that enough precautions against the damage of coir geotextile during construction should be taken. A thin cushion layer (preferable 50 mm) shall be provided at the top of coir geotextile to avoid damages to the geotextile at the time of construction. The instructions given in the above section should be followed to ensure quality control of the coir geotextile.

5.4 Limitations of Coir Geotextile

1. Biodegradability is often considered as a disadvantage of coir geotextile for utilizing it as subgrade reinforcement. Even though the pavement becomes less dependent on geotextile in the long term due to consolidation, treatment of coir geotextiles with suitable chemical agent would help in reduction of the loss in reinforcement effect.
2. Use of coir geotextile over subgrade with high organic content and pH level of 6-8 accelerates the degradation process (Balan et al., 2016).
3. The production of coir geotextiles is limited to the coconut producing states of the country.
4. Coir geotextiles are hygroscopic in nature, hence proper packing should be ensured during transportation and storage.

6. QUALITY CONTROL TESTS FOR COIR GEOTEXTILES (CGT)

Selection of the right type of CGT for a specific application is of vital importance. As there is hardly any difference between CGT and man-made Geotextiles functionally, the manual relies on the standards available for man-made geotextiles. As the test standards of such geotextiles are not uniform in developed countries, references have been drawn from the American Standards (ASTM standards) for the sake of uniformity, where Indian standards are not available. A sample Bill of Quantities (BOQ) and brief description on quality control of coir geotextile to be used as reinforcement is also attached as **Annexure B**.

The section has been divided into three categories:

Physical Properties

Mechanical Properties

Hydraulic Properties

6.1 Physical Properties

Physical properties mentioned in this subsection refer to CGT as presently manufactured. They are indicative only and not the critical design properties of the product.

6.1.1 Mass per Unit Area

This is an important property having a direct impact on the cost and mechanical properties. The method of determining the mass per unit area of the geotextile should comply Clause 2.2.1.2 of IRC:SP:59. After 24 hours of conditioning at standard ambient temperature, $27 \pm 2^\circ\text{C}$ and relative humidity, $65 \pm 5\%$, tests should be conducted to determine the mass per unit area.

6.1.2 Thickness

This is an important property in connection with transmissivity of CGT. It is measured between the upper and lower surfaces of the CGT at a specified pressure. ASTM D 5199/IS 15868 Part 2 stipulates that the accuracy should be at least 0.02 mm under a pressure of 2 kPa. Thickness of commonly used CGT ranges from 0.2 mm to 10 mm. The method of determining the thickness of the geotextile should comply Clause 2.2.1.3 of IRC:SP:59.

6.1.3 Porometry

This is a critical property for permittivity and soil retention. CGT can be manufactured with open weave like nets or as closely woven fabrics. A finer pore size of CGT treated with rot resistant chemicals/bitumen reduces OAR (Open Area Ratio) which further reduces permittivity of CGT and induces clogging. The method of determining the apparent opening size of the geotextile should comply Clause 2.2.3.1 of IRC:SP:59. The pore size of CGT can be measured by two methods:

By reverse dry sieving technique

Special glass beads of known size are vibrated on the CGT fabric having unconfirmed mesh size or porometry. The percentage of the glass beads passing through it is recorded and the test is repeated for successive smaller grades of glass beads. The pore size grading curve may be drawn on the basis of the findings and mesh size is calculated.

By using an overhead projector

In case of CGT having large rectangular pores, overhead projector is used to determine the pore size. CGT specimen of known dimension is placed on the projector and the dimensions of the projected specimen noted. By applying the ratio-proportion method, mesh size of the specimen can be determined by measuring the projected mesh size in both directions.

6.2 Mechanical Properties

Mechanical properties of CGT are basically indicative of the resistance of product to mechanical stresses developed as a result of application of loads and/or installation conditions. The tests that may be used for determining mechanical properties of CGT are tensile strength and tear strength.

6.2.1 Tensile Strength

The test for tensile strength is performed as per ASTM D 4595 and IS 16635. The CGT specimen is

gripped across its entire width in grip jaws and pulled in tension with a constant rate of extension till its failure. While extending the sample, both load and deformation are to be measured and noted. A sample of 200 mm x 200 mm is held across its entire width in the jaws of a tensile testing machine operated at a given rate of strain, applying a longitudinal force to the test specimen until the specimen ruptures. Maximum tensile stress is often referred to as ultimate strength. The method of determining the tensile strength of the geotextile should comply Clause 2.2.2.1 of IRC:SP:59.

6.2.2 Tear Strength

CGT is to be inserted into a tensile testing machine with an initial 150 mm cut (Trapezoidal Tearing Strength Test). The load stretches the fabric before it tears. The test is described in ASTM D4533 / IS 14293. The unit is kilo Newton (kN).

6.3 Hydraulic Properties

Hydraulic properties of CGT are essential for the design of CGT for filtration or drainage applications. Hydraulic properties of geotextiles are controlled by the geotextile's pore sizes, pore size distribution and porosity. Apparent opening size, permittivity, transmissivity are hydraulic properties currently being used as performance criteria for geotextiles.

6.3.1 Transmissivity of CGT

Transmissivity is the property of CGT to transmit flow along its plane and is a function of its thickness and structure and measured as per ASTM D 4491. In this case, the cross-sectional area of flow 'A' would be equivalent to $t_g \times w$, where, t_g is the thickness and w is the width of CGT, transmitting in-plane flow.

Rate of discharge Q would equal $t_g \times w \times k_p \times i$,
Where k_p is the coefficient of normal permeability and 'i' is the hydraulic gradient.

The product $t_g \times k_p$ is called hydraulic transmissivity (θ)
 Q then equals to $\theta \times w \times i$.

It is pertinent to note that in certain types of non-woven CGT, high normal stress reduces transmissivity drastically.

With given values of hydraulic gradient and normal stress level, transmissivity can be deduced by dividing the flow rate ($m^3/s/m$) by the hydraulic gradient.

The geotextile permittivity should comply the Clause 2.2.3.2 of IRC:SP:72.

7. APPLICATION OF COIR GEOTEXTILES FOR RAIN WATER EROSION CONTROL IN ROAD EMBANKMENTS

7.1 Coir Geotextiles

Woven or Non Woven CGT can be used for stabilisation of embankments.

7.2 Mechanism of Soil Erosion

The impact of rain drops and surface wind on exposed soil surfaces of road, railway embankments and hill slopes will cause surface run off particles. This in turn would lead to detachment of soil particles and carried away by the surface runoff. These particles carry seeds and soil nutrients. Natural growth of vegetation on slope is thus hindered.

7.3 Role of Coir Geotextiles in Surface Erosion Control

Coir geotextiles are permeable coir fabrics made from natural coir fibre. CGT control soil erosion by acting as a ground cover. As a ground cover, it reduces the flow velocity of run off water by forming check dams which is in firm contact with soil and arrests the surface flow of rain water. It absorbs the impact of water flow and resist washing down keeping the soil intact. It also protects the soil against the rain splash erosion of the top soil. It reduces the flow velocity of runoff water by virtue of its surface formation.

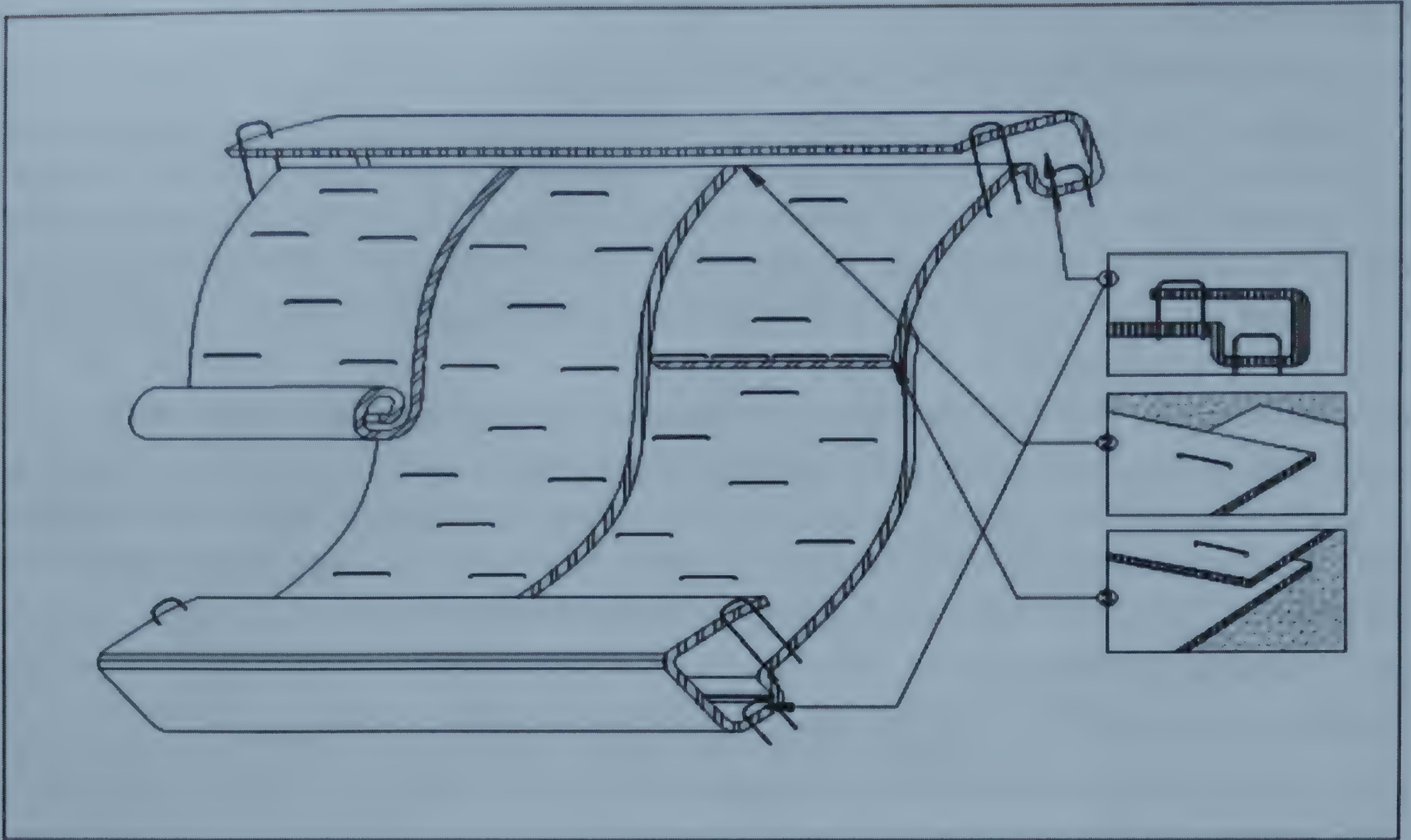
7.4 Selection of Coir Non Woven Composite Geo-Textiles/Coir Stitched Blankets

The choices of Coir Geotextiles basically depend on the type of soil to be protected. It requires to be ensured primarily that the slope to be protected from rainwater erosion is geo-technically stable. It also required considering the extreme rainfall in a limited time span at that location as the intensity of rainfall is more important than the average annual rainfall.

7.5 Installation Method

The stages of laying of CGT on slopes for rain water erosion control are as under:

- a) The slope shall be made free from undulations, soil slurry, mud and sharp projections and compacted with additional earth where necessary.
- b) Anchoring trenches should be excavated at the top and toe of the slope (300 mm x 300 mm). The top trench should be sufficiently away from the edge of the slope considering the stability of the slope.
- c) The selected CGT shall be unrolled across the top trench and along the slope downward caring to see that it touches the soil surface at all points.
- d) Overlaps shall be minimum 150 mm at sides and ends (see **Fig. 11** section (d) & (e)). The CGT at the higher level on the slope shall be placed over level. Side overlaps of a CGT piece shall be placed over its next piece on one side and under the next piece on the other.
- e) The CGT should be fixed in position by steel staples as shown in the **Fig. 11** (usually of 11 gauge dia, and minimum 300 mm of length of penetration) or by spilt bamboo pegs. Stapling shall be done normally at an interval of 500-750 mm both in longitudinal and transverse directions. Special care shall be taken to staple the CGT within the anchoring trenches (300 mm depth and 300 mm width) both at the bottom and at the sides (see **Fig. 11** section (f) & **Fig. 12**).
- f) The anchoring trenches shall be filled up with brick-bats/soil for preventing displacement of the CGT. Care shall be taken that the overlaps are not displaced during installation.
- g) Care shall be taken to ensure that the CGT is not damaged due to puncture, tear and other operational stresses.



Laying Method & Pin Position

Fig. 12 Laying & Fixing of Coir Geo-textile to Control Rain Water Erosion

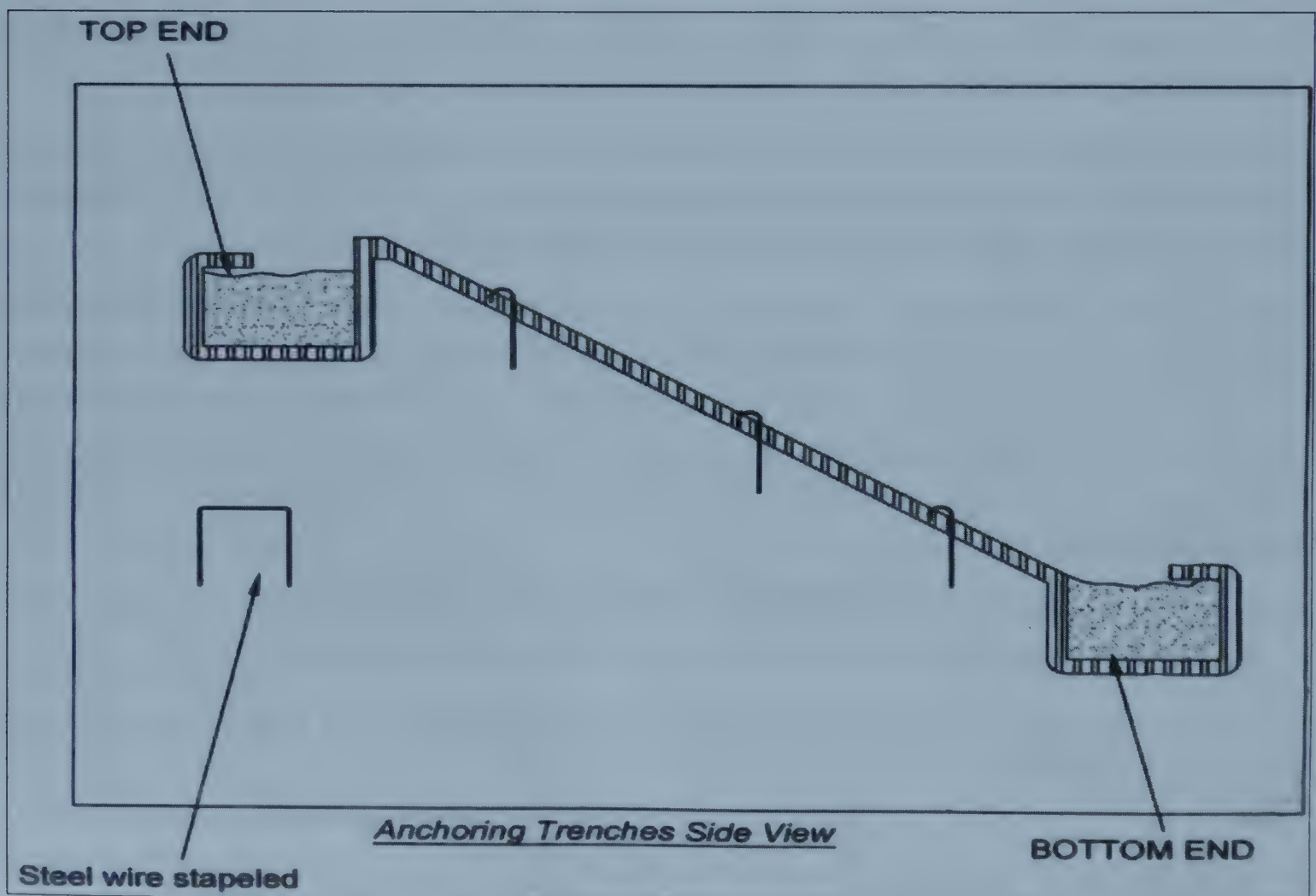


Fig. 13 Fixing and Stapling on Slopes

- h) Seeds of vegetation (grass, legumes, etc, of appropriate variety, preferably local vegetation) should then be spread (refer to **Table 3** for guidance in selecting the species of vegetation and refer to **Table 4** for recommended grasses, plants and trees). If seeds are not available, saplings of the appropriate plant species may be planned at suitable intervals through the opening of the CGT. Hydro seeding with seeds can also be adopted.
- i) In special circumstances, a second dose of seeds may be spread with dibbling of locally available grass.
- j) Installation should be completed preferably before the monsoon to take advantage of the rains for quick germination of seeds.

The scope of this particular guidelines is limited only for low volume roads. However, application of coir geotextile as an erosion control membrane in highway embankment is detailed in this Chapter. The possibility of coir geotextile as a reinforcement in highway can be explored by conducting experimentations including traffic and climatic conditions and the properties of the subgrade.

Table 3 Guidance in Selecting the Species of Vegetation

S.No	Name of the Species	Suited for
1.	Chrysopogon zizanioides (khus - khus)	All type of soil
2.	Avicennia officinalis	Shrub suitable for marshy places
3.	Rhizophora Mucrunata	Shrub suitable for marshy places
4.	Cyperus Exaltatus	Grass suitable for highway slopes
5.	Acrostichum Aureum	Shrub suitable for dam sites
6.	Adiantum spices	Shrub suitable for dam sites
7.	Cyanodon dactylon	For light sandy soils
8.	Cenehurs ciliaries	For most types of soil
9.	Eragrostis curuvla	For protecting terraces and channels
10.	Dianthum annulatum	For light soil
11.	Pennisetum pedicellatum	Sandy loam soil
12.	Both rochola glabra	For red semi arid soil
13.	Stylosanthis gracilis	For light soils with low moisture
14.	Stylosamthis gusineusis	For light and medium soil with low moisture
15.	Pucraria hirsute	Cover crop suited to alluvial soil and For hills in humid climate
16.	Pennisetum purpureum	For hill slopes
17.	Peuraria hirsta	Cover crop suited to alluvial soil

**Table 4 Grasses Recommended for Soil Moisture Conservation
(SMC) and Slope Stabilization**

Sl. No.	Species	Propagation method
1.	Bambusa arundinacea	Rhizome/Seeds
2.	Bothriochloa pertusa	Seeds
3.	Chrysopogon fulvus	Slips
4.	Cymbopogon citratus	Slips/Seeds
5.	Cymbopogon flexuosus	Slips
6.	Cymbopogon martini	Slips
7.	Cymbopogon nardus	Slips
8.	Chrysopogon zizanioides (khus - khus)	Slips
9.	Cynodon dactylon	Rhizome/Seeds
10.	Dendrocalamus strictus	Rhizome
11.	Dichanthium annulatum	Seeds
12.	Eleusine indica	Slips/Seeds
13.	Heteropogon contortus	Slips/Seeds
14.	Pennisetum pedicellatum	Seeds
15.	Saccharum spontaneum	Slips

REFERENCES

- Anusudha, V., V. Sunitha, and S. Mathew, 2020, “Performance of Coir Geotextile Reinforced Subgrade for Low Volume Roads”, International Journal of Pavement Research and Technology, <https://doi.org/10.1007/s42947-020-0325-4>.
- ASTM 2015, “Standard Test Method for Trapezoid Tearing Strength of Geotextiles”, ASTM D4533, West Conshohocken, PA: ASTM.
- ASTM 2017, “Standard Test Method for Tensile Properties of Geotextiles by the Wide-Width Strip Method”, ASTM D4595, West Conshohocken, PA: ASTM.
- ASTM 2018, “Standard Test Method for Density of Plastics by the Density-Gradient Technique”, ASTM D1505, West Conshohocken, PA: ASTM.
- ASTM 2019, “Standard Test Method for Measuring the Nominal Thickness of Geosynthetics”, ASTM D5199, West Conshohocken, PA: ASTM.
- ASTM 2020, “Standard Test Method for Tensile Strength and Young's Modulus of Fibers”, ASTM C1557, West Conshohocken, PA: ASTM.
- ASTM 2020, “Standard Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement”, ASTM D792, West Conshohocken, PA: ASTM.
- ASTM 2020, “Standard Test Methods for Determining Apparent Opening Size of a Geotextile”, ASTM D4751, West Conshohocken, PA: ASTM.
- ASTM 2020, “Standard Test Methods for Water Permeability of Geotextiles by Permittivity”, ASTM D4491, West Conshohocken, PA: ASTM.
- Balan, K., Sheela Evangeline, Y., and Venkatappa Rao, G. (2016), “Coir Geotextiles (Coir Bhoovastra) for Sustainable Infrastructure”, Publication No. 331, Central Board of Irrigation and Power and Indian Chapter of International Geosynthetics Society.
- BIS (Bureau of Indian Standards), 1966, “Method for Determination of Bundle Strength (Tenacity) of Cotton Fibre”, IS 3675, New Delhi, India: BIS.
- BIS (Bureau of Indian Standards), 1988, “Part 1 to 6: Coir Matting, Mourzouks and Carpets”, IS 12503, New Delhi, India: BIS.
- BIS (Bureau of Indian Standards), 1991, “Geotextiles – Methods of Test, Part 2 – Determination of Resistance to Exposure of Ultra-Violet Light and Water (Xenon Arc Type Apparatus)”, IS 13162, New Delhi, India: BIS.
- BIS (Bureau of Indian Standards), 1992, “Determination of Tensile Properties of Extruded Polymer Geogrids Using the Wide Strip – Test Method”, IS 13325, New Delhi, India: BIS.
- BIS (Bureau of Indian Standards), 1992, “Geotextiles – Methods of Test, Part 5 – Determination of Tensile Properties Using a Wide Width Strip”, IS 13162, New Delhi, India: BIS.
- BIS (Bureau of Indian Standards), 1995, “Geotextiles – Methods of Test for Determination of Water Permeability-Permittivity”, IS 14324, New Delhi, India: BIS.
- BIS (Bureau of Indian Standards), 1995, “Geotextiles – Method for Determination of Apparent Opening Size by Dry Sieving Technique”, IS 14294, New Delhi, India: BIS.

- BIS (Bureau of Indian Standards), 1995, “Geotextiles – Method of Test for Trapezoid Tearing Strength”, IS 14293, New Delhi, India: BIS.
- BIS (Bureau of Indian Standards), 1995, “Geotextiles – Method of Test for Trapezoid Tearing Strength”, IS 14293, New Delhi, India: BIS.
- BIS (Bureau of Indian Standards), 2008, “Part 1 to 6: Natural Fibre Geotextiles (Jute Geotextile and Coir Bhoovastra) – Methods of Test”, IS 15868, New Delhi, India: BIS.
- BIS (Bureau of Indian Standards), 2008, “Textiles – Open Weave Coir Bhoovastra”, IS 15869, New Delhi, India: BIS.
- BIS (Bureau of Indian Standards), 2009, “Use of Coir Geotextiles (Coir Bhoovastra) in Unpaved Roads - Guidelines”, IS 15871, New Delhi, India: BIS.
- BIS (Bureau of Indian Standards), 2012, “Textiles – Test Methods for Nonwovens, Part 7 – Determination of Bending Length”, IS 15891, New Delhi, India: BIS.
- BIS (Bureau of Indian Standards), 2017, “Geosynthetics -Wide – Width – Tensile Test”, IS 16635, New Delhi, India: BIS.
- Coir Board (2011), “Indian Coir: A Reference Book, Ministry of Micro, Small & Medium Enterprises (MSME),” Government of India, Kochi,
- Hejazi, S. M., M. Sheikhzadeh, S. M. Abtahi, and A. Zadhoush, 2012, “A Simple Review of Soil Reinforcement by Using Natural and Synthetic Fibers”, *Construction and Building Materials* 30:100-116.
- IRC (Indian Roads Congress), 2015, “Guidelines for the Design of Flexible Pavements for Low Volume Rural Roads”, IRC:SP:72, New Delhi, India: IRC.
- IRC (Indian Roads Congress), 2019, “Guidelines for Use of Geosynthetics in Road Pavements and Associated Works”, IRC:SP:59, New Delhi, India: IRC.
- MORD (Ministry of Rural Development), 2014, “Specifications of Rural Roads”, New Delhi, India: IRC.
- Rao, G. V., E. Y. Sheela, and M. K. Sayida, 2020, “Application of Coir Geotextiles in Rural Roads of India”, *Indian Geotechnical Journal* 50 (2):172-183.
- Sayida, M. K., S. Y. Evangeline, and M. S. Girish, 2019, “Coir Geotextiles for Paved Roads: a Laboratory and Field Study Using Non-Plastic Soil as Subgrade”, *Journal of Natural Fibres*, doi:10.1080/15440478.2019.1568344.
- Sridhar, R., and M. T. P. Kumar, 2018, “Experimental Investigation of Load Settlement Behavior of Coir Mat and Coir Fiber Reinforced Sand”, *Journal of Natural Fibers* 15:452-463.
- Subaida, E. A., S. Chandrakaran, and N. Sankar, 2009, “Laboratory Performance of Unpaved Roads Reinforced with Woven Coir Geotextiles”, *Geotextiles and Geomembrane* 27:204-210.
- Tiwari, N., and N. Satyam, 2020, “An Experimental Study on the Behaviour of Lime and Silica Fume Treated Coir Geotextile Reinforced Expansive Soil Subgrade”, *Engineering Science and Technology*, doi:10.1016/j.jestch.2019.12.006.
- Visvanathan, A., S. Velayudhan, and S. Mathew, 2020, “Field Evaluation of Coir Geotextile Reinforced Subgrade for Low Volume Pavements”, *Journal of Natural Fibers*, doi:10.1080/15440478.2020.1758279.

SOLVED DESIGN EXAMPLE

Elastic modulus values obtained from various field tests:

Table A Geogauge and Plate Load Test Results

Test Section		Subgrade Elastic Modulus E (MPa)		
		Geogauge results	Plate load test results	Dynamic cone penetration test results
Control section		48.5	46.9	49.9
Subgrade reinforced with	700 gsm	68.5	69.8	106.0
	700 gsm	71.8	66.0	100.5
	400 gsm	59.0	61.5	85.0
	400 gsm	61.0	58.7	74.9

Step 1: Subgrade CBR = 3%

Step 2: Design traffic = 0.06 – 0.1 msa

Step 3: Conventional pavement section for 3-4% CBR as per IRC: SP: 72-2015

GSB = 175 mm; WBM = 75 mm; WBM gr III = 75 mm

Step 4: Elastic modulus for different layers of conventional section

Subgrade = 30 MPa (as per IRC:37-2018, $E = \text{CBR} \times 10$)

GSB = 61.3 MPa (as per IRC:37-2018, $E_{\text{Granular layer}} = 0.2 \times (h)^{0.45} \times E_{\text{Support}}$)

Base = 116.87 MPa (as per IRC:37-2018, $E_{\text{Granular layer}} = 0.2 \times (h)^{0.45} \times E_{\text{Support}}$)

Step 5: Determination of Modulus Improvement Factor (MIF)

From the field tests conducted on the subgrade of unreinforced and coir geotextile reinforced roads, the value of MIF is calculated from the formula,

$$\text{Modulus Improvement Factor} = \frac{\text{Elastic modulus of reinforced subgrade}}{\text{Elastic modulus of unreinforced subgrade}}$$

As per Geogauge test results, MIF = 1.41-1.48 (700 gsm); 1.22-1.26 (400 gsm)

As per Plate load test results, MIF = 1.41-1.49 (700 gsm); 1.25-1.31 (400 gsm)

As per DCP results, MIF = 2.0-2.12 (700 gsm); 1.5-1.7 (400 gsm)

For safer side, adopting the least MIF obtained from Geogauge test results,

MIF for subgrade reinforced with 700 gsm mass density = 1.41

MIF for subgrade reinforced with 400 gsm mass density = 1.22

Step 6: Elastic modulus for different layers of coir geotextile reinforced section

For 700 gsm geotextile reinforced section,

Subgrade = MIF * 30 MPa = 42.3 MPa

GSB = 86.44 MPa (as per IRC:37-2018, $E_{\text{Granular layer}} = 0.2 \times (h)^{0.45} \times E_{\text{Support}}$)

$$\text{Base} = 164.82 \text{ MPa (as per IRC:37-2018, } E_{\text{Granularlayer}} = 0.2 \cdot (h)^{0.45} \cdot E_{\text{Support}})$$

For 400 gsm geotextile reinforced section,

$$\text{Subgrade} = \text{MIF} \cdot 30 \text{ MPa} = 36.6 \text{ MPa}$$

$$\text{GSB} = 74.79 \text{ MPa (as per IRC:37-2018, } E_{\text{Granularlayer}} = 0.2 \cdot (h)^{0.45} \cdot E_{\text{Support}})$$

$$\text{Base} = 142.61 \text{ MPa (as per IRC:37-2018, } E_{\text{Granularlayer}} = 0.2 \cdot (h)^{0.45} \cdot E_{\text{Support}})$$

Step 7: Determination of design thickness different layers of reinforced section by analysis using IITPAVE

Using the Elastic modulus values computed above for conventional section and Poisson's ratio = 0.35, The maximum vertical compressive strain at the top of subgrade is $\epsilon_v = 0.00238$;

- **Design for 700 gsm geotextile reinforced section**

Using the Elastic modulus values computed for 700 gsm geotextile reinforced section and Poisson's ratio = 0.35,

For same section adopted for conventional design as per IRC:SP:72-2015,

i.e. Base = 150 mm and GSB = 175 mm,

$$\epsilon_{v1} = 0.00169$$

Since $\epsilon_{v1} < \epsilon_v$ the section is safe.

For 25 mm reduction in GSB in the conventional design as per IRC:SP:72-2015,

i.e. Base = 150 mm and GSB = 150 mm,

$$\epsilon_{v2} = 0.00192$$

Since $\epsilon_{v2} < \epsilon_v$ the section is safe.

For 50 mm reduction in GSB in the conventional design as per IRC:SP:72-2015,

i.e. Base = 150 mm and GSB = 125 mm,

$$\epsilon_{v3} = 0.00223$$

Since $\epsilon_{v3} < \epsilon_v$ the section is safe.

For 75 mm reduction in GSB in the conventional design as per IRC:SP:72-2015,

i.e. Base = 150 mm and GSB = 100 mm,

$$\epsilon_{v4} = 0.00254$$

Since $\epsilon_{v4} > \epsilon_v$ the section is not safe.

Hence the design thickness is

WBM gr III = 75 mm, WBM = 75 mm and GSB = 125 mm

- **Design for 400gsm geotextile reinforced section**

For same section adopted for conventional design as per IRC:SP:72-2015,

i.e. Base = 150 mm and GSB = 175 mm,

$$\epsilon_{v1} = 0.00192$$

Since $\epsilon_{v1} < \epsilon_v$ the section is safe.

For 25 mm reduction in GSB in the conventional design as per IRC:SP:72-2015,

i.e. Base = 150 mm and GSB = 150 mm,

$$\epsilon_{v2} = 0.00225$$

Since $\epsilon_{v2} < \epsilon_v$ the section is safe.

For 50 mm reduction in GSB in the conventional design as per IRC:SP:72-2015,

i.e. Base = 150 mm and GSB = 125 mm,

$$\epsilon_{v3} = 0.00254$$

Since $\epsilon_{v3} > \epsilon_v$ the section is not safe.

Hence the design thickness is

WBM gr III = 75 mm, WBM = 75 mm and GSB = 150 mm

After an extensive trial and error analysis, the optimum thicknesses of the granular layers were arrived and it is shown in **Fig. 8** and **9**.

ANNEXURE - B**SAMPLE OF BILL OF QUANTITIES (BOQ)**

Sl. No.	Description	Unit of Measurement	Quantity	Rate
1)	Coir Geotextile			
	“Supplying, testing and installation of 100 cm wide woven Coir Geo-textiles (CGT) 700/900/400 gms/sq.m, with minimum thickness of 6.5 mm and length not less than 50 m. It should satisfy all requirements as laid down in IS 15869:2020. Coir geotextile should be laid with overlaps of 100 mm in transverse direction and 300 mm longitudinally, duly secured to sub-grade by U shaped MS staples (11 gauge) at an interval of 750 mm or as per direction of the Engineer-in-charge. The rate is inclusive of all Govt. taxes, duties, cess as leviable, transportation from a coir geotextile manufacturer empanelled with Coir Board to the work site, in/c loading and unloading and storage of the material at site etc.” The CGT has to be inspected under Coir Mark Scheme of Coir Board before Despatch.	Sq. M.		

(The Official amendments to this document would be published by the IRC in its periodical, 'Indian Highways' which shall be considered as effective and as part of the Code/Guidelines/Manual, etc. from the date specified therein)

**Price: ₹ 400/-
(Plus Packing & Postage)**